EVALUATION PROGRAM

for

SECONDARY SPACECRAFT CELLS

ACCEPTANCE TEST
OF
GULTON INDUSTRIES, INC.
20 AMPERE–HOUR STANDARD AND
ADHYDRODE NICKEL–CADMIUM CELLS

prepared for
GODDARD SPACE FLIGHT CENTER
CONTRACT W11,252B

QUALITY EVALUATION LABORATORY

NAD CRANE, INDIANA

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UNITED STATES NAVAL AMMUNITION DEPOT
CRANE, INDIANA

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STANDARD AND ADHYDRODE NICKEL-CADMIUM
SECONDARY SPACECRAFT CELLS

QE/C 68-14 2 FEBRUARY 1968

PREPARED UNDER THE DIRECTION OF

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Enclosure (1)

REPORT BRIEF

GULTON 20.0 AMPERE-HOUR

STANDARD AND ADHYDRODE NICKEL-CADMIUM

SECONDARY SPACECRAFT CELLS

Ref: (a) National Aeronautics and Space Administration Purchase Order Number W11,252B
(b) NASA ltr BRA/VBK/pad of 25 September 1961 w/BUWEPS first end FQ-1:WSK of 2 October 1961 to CO NAD Crane
(c) Preliminary Work Statement for Battery Evaluation Program of 25 August 1961

I. TEST ASSIGNMENT BRIEF

A. In compliance with references (a) and (b), evaluation of 20.0 ampere-hour standard and adhydrode secondary spacecraft cells was begun according to the program outline of reference (c).

B. The object of this evaluation program is to gather specific information concerning secondary spacecraft cells. Information concerning performance characteristics and limitations, including cycle life under various electrical and environmental conditions, will be of interest to power systems designers and users. Cell weaknesses including causes of failure of present designs will be of interest to suppliers as a guide to product improvement.

C. Fifty-four (30 standard and 24 adhydrode) 20.0 ampere-hour cells (manufacturer's rating) were purchased from Gulton Industries, Inc., Metuchen, New Jersey by National Aeronautics and Space Administration (NASA).

II. CONCLUSIONS

A. From the results of this test, it can be concluded that:

1. The ceramic seals used by Gulton Industries, Inc. are satisfactory as evidenced by no leakers out of the 54 cells tested.

2. The capacity of the 54 cells was in the acceptable range of 24.7 to 27.3 ampere-hours.

III. RECOMMENDATIONS

A. It is recommended that these Gulton Industries, Inc., 20.0 ampere-hour cells be accepted on the basis of the acceptance test results.

RESULTS OF ACCEPTANCE TESTS

OF

20 AMPERE-HOUR STANDARD AND ADHYDRODE NICKEL-CADMIUM

SECONDARY SPACECRAFT CELLS

MANUFACTURED BY

GULTON INDUSTRIES, INC.

I. INTRODUCTION

A. On 25 September 1967, this activity began acceptance tests on 30 standard and 24 adhydrode 20 ampere-hour cells. These tests were completed on 15 November 1967.

II. TEST CONDITIONS

A. All acceptance tests were performed at an ambient temperature between 23° C and 27° C at existing relative humidity and atmospheric pressure, and consisted of the following:

1. Phenolphthalein Leak Test.
2. Capacity Test.
3. Cell Short Test.
4. Immersion Seal Test.
5. Overcharge Test.
6. Internal Resistance of the Adhydrode only.
7. Internal Resistance of the Cells.
8. Immersion Seal Test.

B. All charging and discharging was done at constant current (± 5 percent). Cells were charged in series but discharged individually.

III. CELL IDENTIFICATION AND DESCRIPTION

A. Cells were identified by the manufacturer's serial numbers although not consecutively from 658 to 693 for the standard cells, and from 206 to 268 for the adhydrode cells.

B. The two types of 20 ampere-hour cells are rectangular in shape with average heights (base to top of terminal), lengths, widths and weights as follows:

Type	Height (Inches)	Length (Inches)	Width (Inches)	Weight (Grams)
Standard	6.933	0.888	2.975	890.0
Adhydrode	6.935	0.885	2.976	903.5

The individual cell dimensions and weights are given in Table I for the standard cells and in Table II for the adhydrode cells. Figures 1 and 2 are photographs of the standard and adhydrode 20 ampere-hour cells.

C. The cell containers or cans, and the cell covers are made of stainless steel. Both terminals of each cell type are insulated from the cell covers by new type ceramic seals and protrude through the covers as solder type terminals.

D. These cells, rated by the manufacturer at 20.0 ampere-hours, were supplied in a discharged (with individual shorting wires) condition.

IV. TEST PROCEDURES AND RESULTS

A. Phenolphthalein Leak Test:

1. The phenolphthalein leak test is a determination of the condition of the welds and ceramic seals on receipt of the cells. This test was performed with a phenolphthalein spray indicator solution of one half of one percent concentration.

2. There were no signs of leakage on any of the 54 cells subjected to the leak test.

B. Capacity Test:

1. The capacity test is a determination of the cell capacity at the c/2 discharge rate, where c is the manufacturer's rated capacity, to a cutoff voltage of 1.00 volt per cell. The discharge was made after a 1-hour open circuit period following the 16-hour charge at the c/10 rate. A total of three capacity checks were made at this activity. The cells were discharged individually, but were recharged in series.

2. In order to gather data on the characteristics of the adhydrode, 51 ohms resistance was used between the adhydrode and

the negative terminal for the first capacity check; 24 ohms was used for the second capacity check; and an open circuit of infinite resistance was used for the third capacity check.

3. Since no data was submitted by the manufacturer, it was not possible to compare the test results of this activity with those of the manufacturer. The individual capacities of the 20 ampere-hour standard cells ranged from 24.7 to 27.3 ampere-hours for an average of 26.3 ampere-hours. The individual capacities of the adhydrode cells ranged from 25.3 ampere-hours to 27.0 ampere-hours for an average of 26.1 ampere-hours. The cell capacities of the standard cells are given in Table III. The cell capacities and the adhydrode voltage characteristics for the adhydrode cells are shown in Table IV. Characteristic 2-hour rate discharge curves for the two types of cells are shown in Figures 3 and 4.

C. Cell Short Test:

1. The cell short test is a means of detecting slight shorting conditions which may exist because of imperfections in the insulating materials, or damage to the element in handling or assembly.

2. Following completion of the third capacity discharge test, each individual cell was loaded with a resistor of value giving a c/1 to c/5 discharge rate and allowed to stand 16 hours with the resistor acting as a shorting device. At the end of 16 hours, the resistors were removed and the cells were placed on open circuit stand for 24 hours. Any cell whose voltage did not recover to 1.15 volts or higher was rejected.

3. The open circuit cell voltages, 24 hours after removal of the shorting resistors, ranged from 1.17 to 1.24 volts for an average of 1.20 volts on the standard cells and from 1.17 to 1.19 volts for an average of 1.18 volts on the 22 accepted adhydrode cells.

4. Two of the adhydrode cells were rejected because of low voltage (0.92 and 0.95 volts) and after completion of the acceptance tests, were returned to Goddard Space Flight Center. The voltage values for the 54 cells are shown in Tables III and IV.

D. Immersion Seal Test:

1. The immersion seal test is a means of detecting leakage of a seal or weld. The test was performed before and after the overcharge test sequence to determine the presence and cause of leaks.

2. The cells were placed under water in a bell jar container. A vacuum of 20 inches of mercury was held for 3 minutes. Cells discharging a steady stream of bubbles were considered rejects.

3. One of the adhydrode cells was rejected because of leakage around the swagelok fitting for the pressure transducer. This defect would not have been present on flight orientated cells.

E. Overcharge Test:

1. The overcharge tests were performed to determine the steady state voltage at specific rates. The test specified a series of constant current charges at c/20, c/10 and c/5 rates, for a minimum of 48 hours at each charge rate or until the increase of the "on-charge" voltage was less than 10 millivolts per day.

2. The cells were monitored hourly throughout the test. Charging was to be discontinued on cells which exceeded 1.50 volts while on charge. There was no need to remove any cells from the charging sequence.

3. The steady state voltage of each cell at the end of each 48-hour charge rate test is shown in Tables III and IV. Characteristic overcharge voltage curves are shown in Figures 5 and 6.

F. Internal Resistance Test of the Adhydrode:

1. This test was performed to determine the internal resistance of the adhydrode.

2. During the c/10 charge rate portion of the overcharge test; the voltage drop across the 51-ohm resistor connecting the adhydrode to the negative terminal was measured. The 51 ohm resistor was then shunted with a 1-ohm resistor for 5 to 10 seconds and the voltage drop across the two parallel resistors (0.9808 ohms) was measured. The internal resistance of the adhydrode in ohms was calculated according to the following formula:

$$R = \frac{V1 - V2}{I2 - I1}$$

where V1 = voltage drop in volts across the 51-ohm resistor,
V2 = voltage drop in volts across the 0.9808-ohm resistor,
I1 = current flow in amperes through the 51-ohm resistor,
I2 = current flow in amperes through the 0.9808-ohm resistor.

3. The internal resistance for the adhydrode of each cell is shown in Table V. The values range from 3.42 to 6.99 ohms for the adhydrodes of these 20 ampere-hour cells.

G. Internal Resistance Test of the Cell:

1. This test was performed to determine the internal resistance of the cell.

2. At the completion of the overcharge test, the cells were returned to the c/20 charging rate and given a short pulse (5 to 10 seconds) at the rate of c in amperes. The cell voltages, V1, immediately prior to the pulse; and V2, 5 milliseconds after the pulse, were read on a suitable recording instrument. A CEC high speed oscillograph recorder (28.8 inches of tape per second) was used. The internal resistance of the cell in ohms was calculated according to the following formula:

$$R = \frac{V2 - V1}{Ic - Ic/20}$$

V1 and V2 are in volts, Ic and Ic/20 are in amperes.

3. The internal resistance for each cell is shown in Tables III and V. The values range from 1.58 to 2.63 milliohms for both the standard and adhydrode 20 ampere-hour cells.

TABLE I

GULTON 20 AMPERE-HOUR STANDARD CELLS

Cell Number	Height (Inches)	Length (Inches)	Width (Inches)	Weight (Grams)
658	6.919	0.895	2.980	905.0
659	6.959	0.900	2.972	905.1
660	6.935	0.885	2.975	895.0
661	6.965	0.884	2.980	897.0
662	6.937	0.884	2.975	904.5
664	6.950	0.899	2.970	895.5
665	6.936	0.890	2.970	907.6
666	6.950	0.892	2.970	900.6
667	6.908	0.884	2.980	899.1
668	6.936	0.875	2.975	895.5
669	6.940	0.885	2.950	895.5
670	6.932	0.885	2.975	894.6
671	6.935	0.892	2.975	902.0
672	6.933	0.888	2.983	909.1
673	6.945	0.900	2.970	880.6
674	6.935	0.883	2.975	884.0
675	6.928	0.890	2.975	877.0
676	6.938	0.888	2.975	881.5
677	6.910	0.888	2.980	873.1
678	6.930	0.880	2.980	883.6
679	6.905	0.880	2.974	881.6

TABLE I (contd)

Cell Number	Height (Inches)	Length (Inches)	Width (Inches)	Weight (Grams)
680	6.950	0.880	2.975	869.1
682	6.925	0.885	2.975	872.1
683	6.936	0.890	2.975	885.0
685	6.940	0.885	2.980	883.1
686	6.925	0.885	2.975	882.5
688	6.925	0.890	2.975	889.0
689	6.930	0.890	2.980	884.1
692	6.939	0.890	2.980	889.0
693	6.915	0.885	2.979	868.6

TABLE II

GULTON 20 AMPERE-HOUR ADHYDRODE CELLS

Cell Number	Height (Inches)	Length (Inches)	Width (Inches)	Weight (Grams)
206	6.936	0.880	2.980	899.4
207	6.925	0.880	2.975	892.6
208	6.940	0.889	2.973	910.2*
210	6.939	0.885	2.975	895.0
212	6.920	0.885	2.975	905.0
213	6.944	0.880	2.974	909.4*
214	6.940	0.883	2.975	899.6
217	6.920	0.885	2.985	894.7
218	6.948	0.884	2.972	915.6*
223	6.912	0.884	2.975	902.7*
226	6.916	0.888	2.972	918.0*
229	6.992	0.893	2.984	920.7*
230	6.964	0.880	2.985	921.8*
232	6.938	0.890	2.981	920.6*
244	6.935	0.888	2.975	905.4*
246	6.936	0.890	2.975	909.5
247	6.934	0.885	2.980	924.4*
249	6.944	0.884	2.976	892.2
251	6.940	0.888	2.972	892.2
260	6.935	0.880	2.979	913.5*
265	6.924	0.892	2.974	890.1
266	6.932	0.884	2.976	880.8
267	6.944	0.884	2.973	886.8
268	6.945	0.888	2.972	883.2

* Increased weight caused by gauge fittings.

TABLE III

GULTON 20 AMPERE-HOUR STANDARD CELLS

Cell Number	Capacity Test (ah)	Capacity Test (ah)	Capacity Test (ah)	Cell Short Test (Volts)	Immersion Seal Test	Overcharge c/20 (Volts)	Overcharge c/10 (Volts)	Overcharge c/5 (Volts)	Internal Resistance (Milliohms)	Immersion Seal Test
658	22.8	26.2	25.2	1.20	O.K.	1.41	1.41	1.43	2.11	O.K.
659	22.8	24.7	24.3	1.21	O.K.	1.40	1.41	1.42	2.11	O.K.
660	22.8	26.2	25.5	1.19	O.K.	1.41	1.41	1.43	2.63	O.K.
661	22.8	25.7	25.0	1.19	O.K.	1.41	1.41	1.43	2.63	O.K.
662	22.8	26.2	25.2	1.20	O.K.	1.40	1.41	1.40	2.63	O.K.
664	22.8	26.2	25.2	1.20	O.K.	1.40	1.41	1.46	2.11	O.K.
665	22.8	25.3	24.8	1.19	O.K.	1.41	1.42	1.42	2.11	O.K.
666	22.8	26.2	25.0	1.21	O.K.	1.41	1.41	1.42	2.11	O.K.
667	22.7	26.2	25.5	1.19	O.K.	1.41	1.41	1.42	2.11	O.K.
668	22.8	26.2	25.0	1.21	O.K.	1.41	1.42	1.42	2.11	O.K.
669	22.5	26.2	25.0	1.20	O.K.	1.40	1.41	1.42	2.11	O.K.
670	21.7	26.3	25.2	1.24	O.K.	1.40	1.41	1.41	2.63	O.K.
671	21.7	26.3	25.5	1.19	O.K.	1.41	1.41	1.41	2.63	O.K.
672	21.7	26.3	25.2	1.18	O.K.	1.41	1.41	1.41	2.11	O.K.
673	22.7	26.3	25.0	1.18	O.K.	1.40	1.40	1.39	2.11	O.K.
674	21.7	26.3	25.0	1.21	O.K.	1.40	1.41	1.40	2.11	O.K.
675	21.7	26.3	25.0	1.20	O.K.	1.41	1.41	1.41	2.11	O.K.
676	21.7	26.7	25.7	1.18	O.K.	1.41	1.41	1.41	2.11	O.K.
677	21.7	25.7	25.0	1.19	O.K.	1.41	1.41	1.42	2.11	O.K.
678	21.7	26.3	25.0	1.19	O.K.	1.41	1.42	1.43	2.11	O.K.
679	25.0	26.7	25.0	1.20	O.K.	1.40	1.41	1.41	2.11	O.K.

TABLE III (Contd)

Cell Number	Capacity Test (ah)	Capacity Test (ah)	Capacity Test (ah)	Cell Short Test (Volts)	Immersion Seal Test	Overcharge c/20 (Volts)	Overcharge c/10 (Volts)	Overcharge c/5 (Volts)	Internal Resistance (Milliohms)	Immersion Seal Test
680	25.0	26.7	24.8	1.19	O.K.	1.41	1.41	1.41	2.63	O.K.
682	24.8	26.7	25.0	1.17	O.K.	1.41	1.41	1.41	2.11	O.K.
683	25.0	26.7	24.7	1.20	O.K.	1.40	1.41	1.41	2.11	O.K.
685	24.8	26.7	24.3	1.20	O.K.	1.41	1.41	1.41	2.11	O.K.
686	25.2	27.3	25.0	1.20	O.K.	1.40	1.40	1.40	2.11	O.K.
688	25.2	26.7	24.3	1.19	O.K.	1.41	1.41	1.40	2.11	O.K.
689	25.0	26.7	24.3	1.19	O.K.	1.41	1.41	1.40	2.11	O.K.
692	24.8	26.3	24.3	1.19	O.K.	1.41	1.42	1.41	1.58	O.K.
693	24.8	26.7	24.5	1.20	O.K.	1.41	1.42	1.41	2.11	O.K.

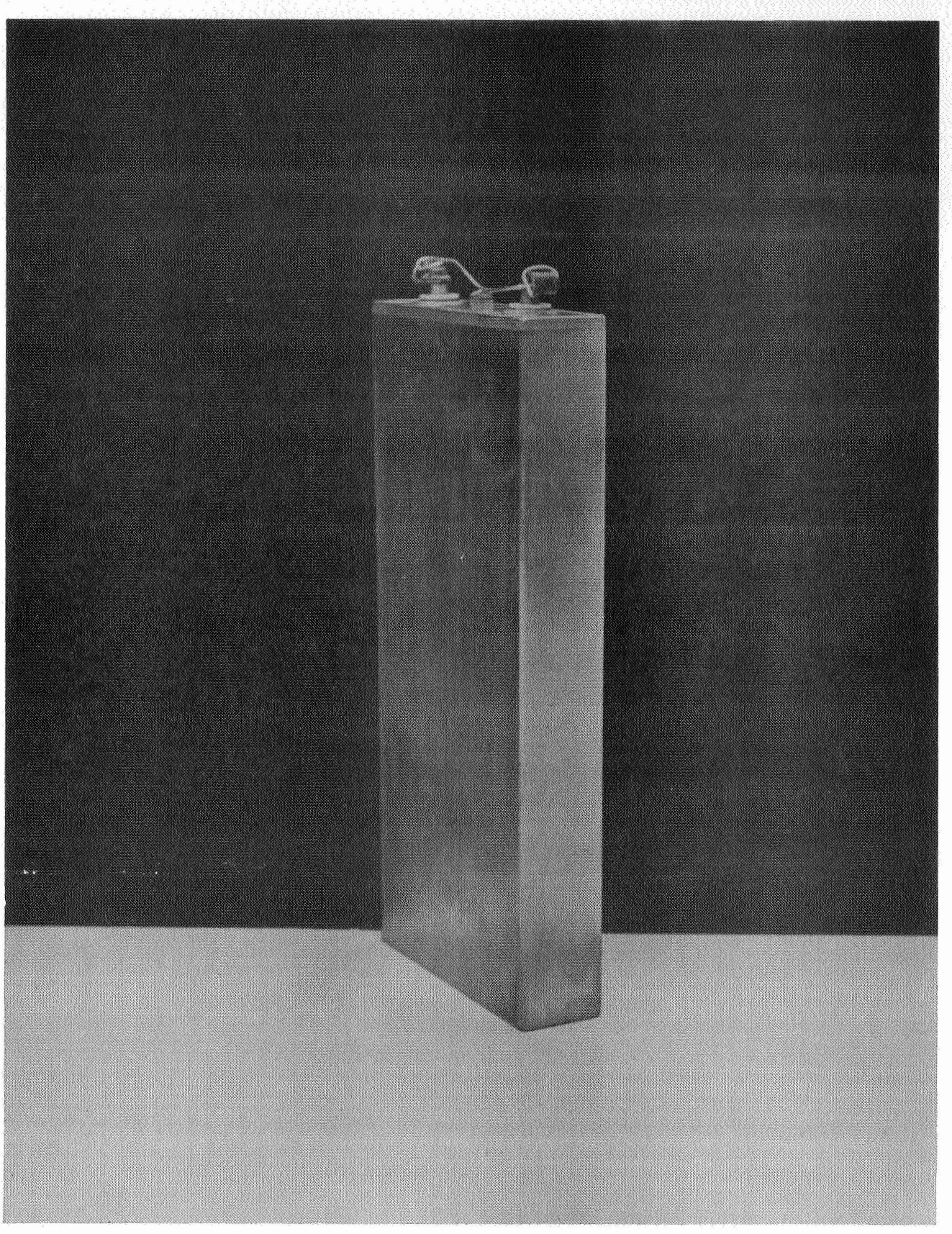
TABLE IV

Cell Number	End of Charge 51 Ohm Resistor Volts	Amps	Capacity No. 1 (ah)	End of Charge 24 Ohm Resistor Volts	Amps	Capacity No. 2 (ah)	End of Charge No Resistor Volts	Amps	Capacity No. 3 (ah)	Cell Short Test (Volts)	c/20 Overcharge Cell Voltage	Third Electrode Volts	Amps	c/10 Overcharge Cell Voltage	Third Electrode Volts	Amps	c/5 Overcharge Cell Voltage	Third Electrode Volts	Amps
206	1.43	0.0055	25.3	1.45	0.0203	26.0	1.44	0.0	25.5	0.95	1.41	0.430	0.0084	1.43	0.602	0.0118	1.43	0.728	0.0143
207	1.43	0.0060	25.5	1.45	0.0199	26.5	1.44	0.0	26.2	1.19	1.41	0.448	0.0088	1.42	0.614	0.0120	1.41	0.729	0.0143
208	1.43	0.0069	25.3	1.45	0.0196	26.0	1.44	0.0	25.5	1.18	1.41	0.467	0.0092	1.42	0.642	0.0126	1.42	0.787	0.0154
210	1.43	0.0059	25.7	1.45	0.0190	25.7	1.43	0.0	24.2	1.18	1.41	0.507	0.0099	1.41	0.663	0.0130	1.41	0.768	0.0151
212	1.43	0.0033	25.5	1.45	0.0199	26.3	1.44	0.0	26.2	1.19	1.41	0.441	0.0086	1.42	0.571	0.0112	1.41	0.716	0.0140
213	1.43	0.0018	25.3	1.45	0.0183	26.8	1.44	0.0	26.3	1.18	1.41	0.158	0.0031	1.42	0.574	0.0113	1.42	0.746	0.0146
214	1.43	0.0059	25.5	1.45	0.0186	26.3	1.44	0.0	25.7	1.18	1.41	0.462	0.0091	1.42	0.601	0.0118	1.42	0.711	0.0139
217	1.43	0.0035	25.5	1.45	0.0189	27.0	1.44	0.0	26.5	1.18	1.41	0.400	0.0078	1.41	0.539	0.0106	1.41	0.640	0.0125
218	1.43	0.0065	24.7	1.45	0.0185	25.3	1.44	0.0	25.0	1.17	1.42	0.454	0.0089	1.42	0.636	0.0125	1.42	0.782	0.0153
223	1.43	0.0057	25.5	1.45	0.0181	26.0	1.44	0.0	25.8	1.18	1.41	0.380	0.0075	1.42	0.489	0.0096	1.42	0.625	0.0123
226	1.43	0.0038	25.7	1.45	0.0195	27.0	1.44	0.0	26.5	1.18	1.41	0.511	0.0100	1.43	0.614	0.0120	1.49	0.203	0.0040
229	1.44	0.0064	25.3	1.45	0.0185	25.8	1.44	0.0	25.3	1.18	1.41	0.417	0.0082	1.42	0.566	0.0111	1.42	0.736	0.0144
230	1.43	0.0062	25.5	1.45	0.0188	25.7	1.44	0.0	25.5	1.18	1.41	0.438	0.0086	1.42	0.616	0.0121	1.42	0.784	0.0154
232	1.43	0.0056	25.5	1.45	0.0190	26.0	1.44	0.0	25.5	0.92	1.41	0.425	0.0083	1.42	0.584	0.0115	1.42	0.758	0.0149
244	1.43	0.0066	25.5	1.45	0.0188	26.0	1.44	0.0	25.5	1.19	1.42	0.473	0.0093	1.43	0.614	0.0120	1.44	0.750	0.0147
246	1.43	0.0064	25.8	1.45	0.0200	26.2	1.44	0.0	25.5	1.19	1.41	0.474	0.0093	1.42	0.641	0.0126	1.43	0.754	0.0148
247	1.43	0.0063	25.5	1.45	0.0187	25.8	1.44	0.0	25.3	1.18	1.42	0.425	0.0083	1.42	0.624	0.0122	1.43	0.753	0.0148
249	1.43	0.0057	25.5	1.45	0.0194	26.2	1.44	0.0	25.5	1.18	1.42	0.452	0.0089	1.42	0.611	0.0120	1.42	0.763	0.0150
251	1.43	0.0062	25.5	1.45	0.0183	26.7	1.44	0.0	26.5	1.18	1.41	0.439	0.0086	1.41	0.638	0.0125	1.41	0.773	0.0152
260	1.43	0.0045	25.5	1.44	0.0200	25.3	1.43	0.0	24.7	1.18	1.41	0.518	0.0102	1.41	0.664	0.0130	1.41	0.781	0.0153
265	1.43	0.0053	25.7	1.44	0.0188	26.7	1.43	0.0	25.2	1.18	1.40	0.436	0.0085	1.40	0.639	0.0125	1.40	0.781	0.0153
266	1.43	0.0057	25.7	1.44	0.0181	25.7	1.43	0.0	25.0	1.18	1.40	0.439	0.0086	1.40	0.588	0.0115	1.40	0.718	0.0141
267	1.43	0.0038	25.5	1.45	0.0195	26.7	1.43	0.0	26.2	1.18	1.41	0.461	0.0090	1.41	0.642	0.0126	1.40	0.796	0.0156
268	1.43	0.0064	25.2	1.44	0.0185	25.3	1.43	0.0	25.2	1.18	1.41	0.416	0.0082	1.42	0.597	0.0117	1.41	0.756	0.0148

TABLE V

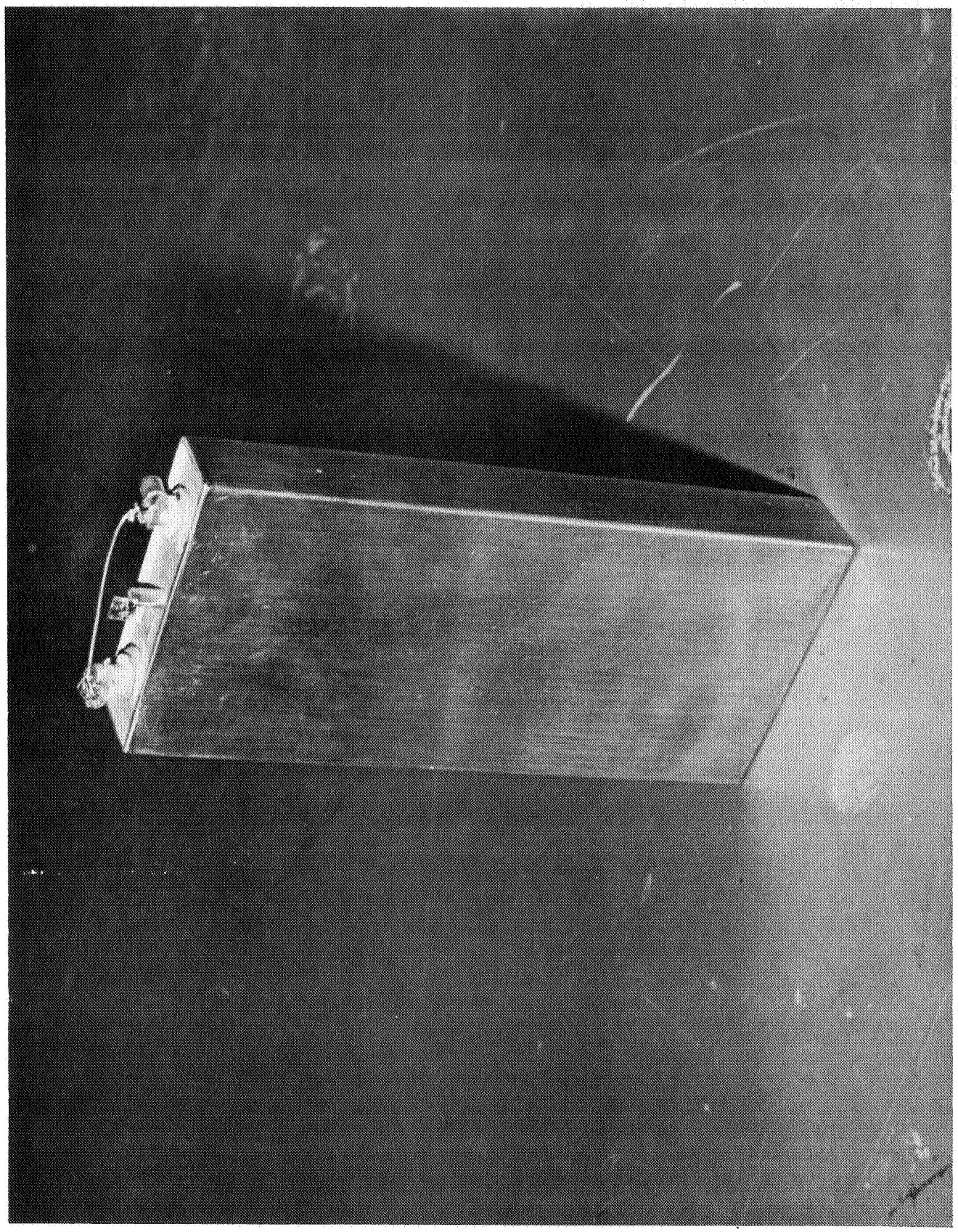
GULTON 20 AMPERE-HOUR ADHYDRODE CELLS

Cell Number	Auxiliary Electrode Resistance (Ohms)	Cell Resistance (Milliohms)
206	4.97	1.58
207	4.58	2.11
208	6.53	2.11
210	4.29	2.63
212	4.27	2.11
213	4.68	2.11
214	4.47	2.11
217	3.42	1.58
218	5.80	2.63
223	3.54	2.63
226	3.88	2.11
229	4.99	2.11
230	5.33	2.11
232	5.47	2.63
244	4.74	2.11
246	5.63	2.63
247	5.58	2.11
249	6.99	2.11
251	5.10	2.11
260	4.84	2.11
265	5.09	1.58
266	4.75	2.11
267	5.97	2.11
268	5.79	2.11



GULTON 20 AMPERE-HOUR STANDARD CELL

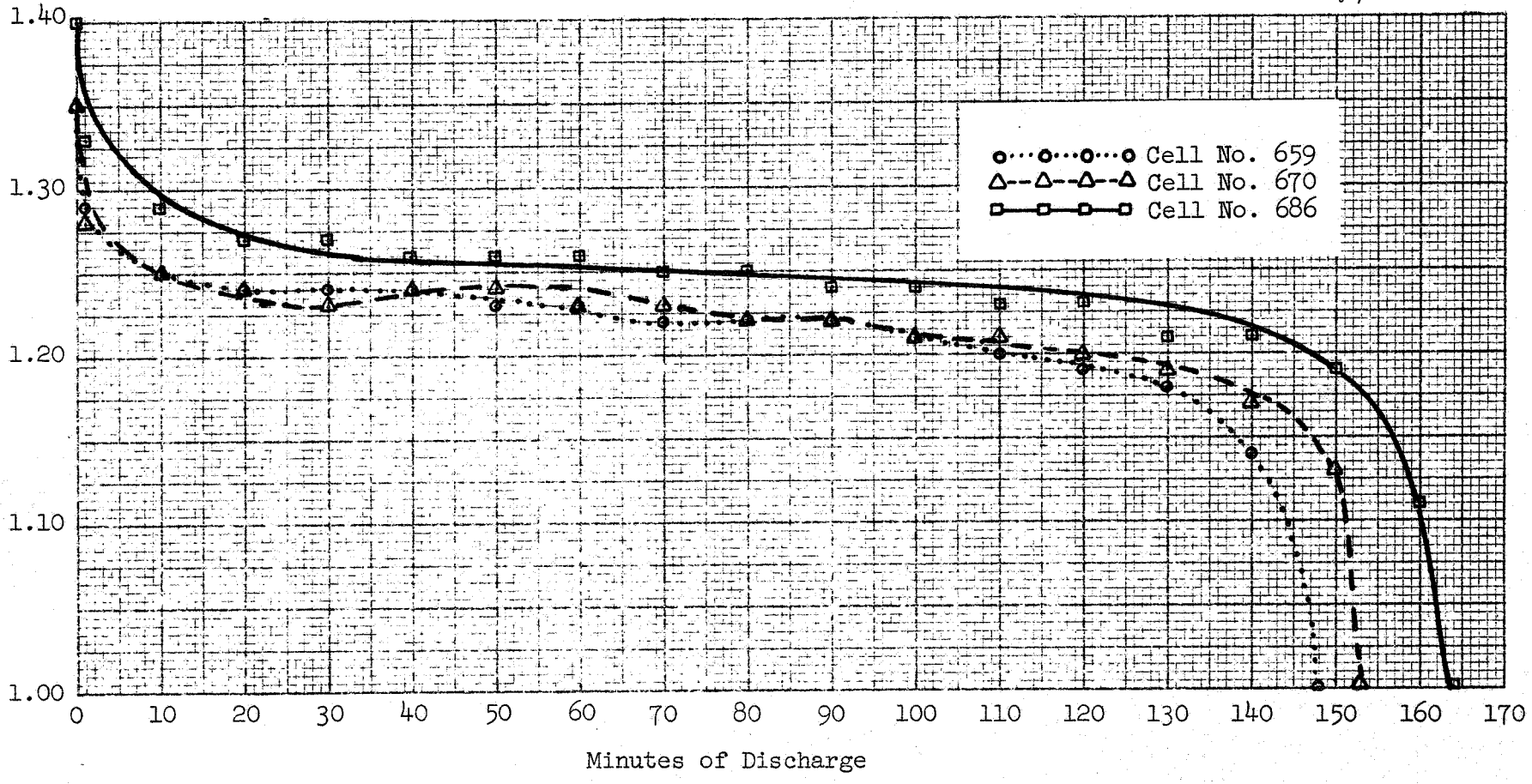
FIGURE 1



GULTON 20 AMPERE-HOUR ADHYDRODE CELL

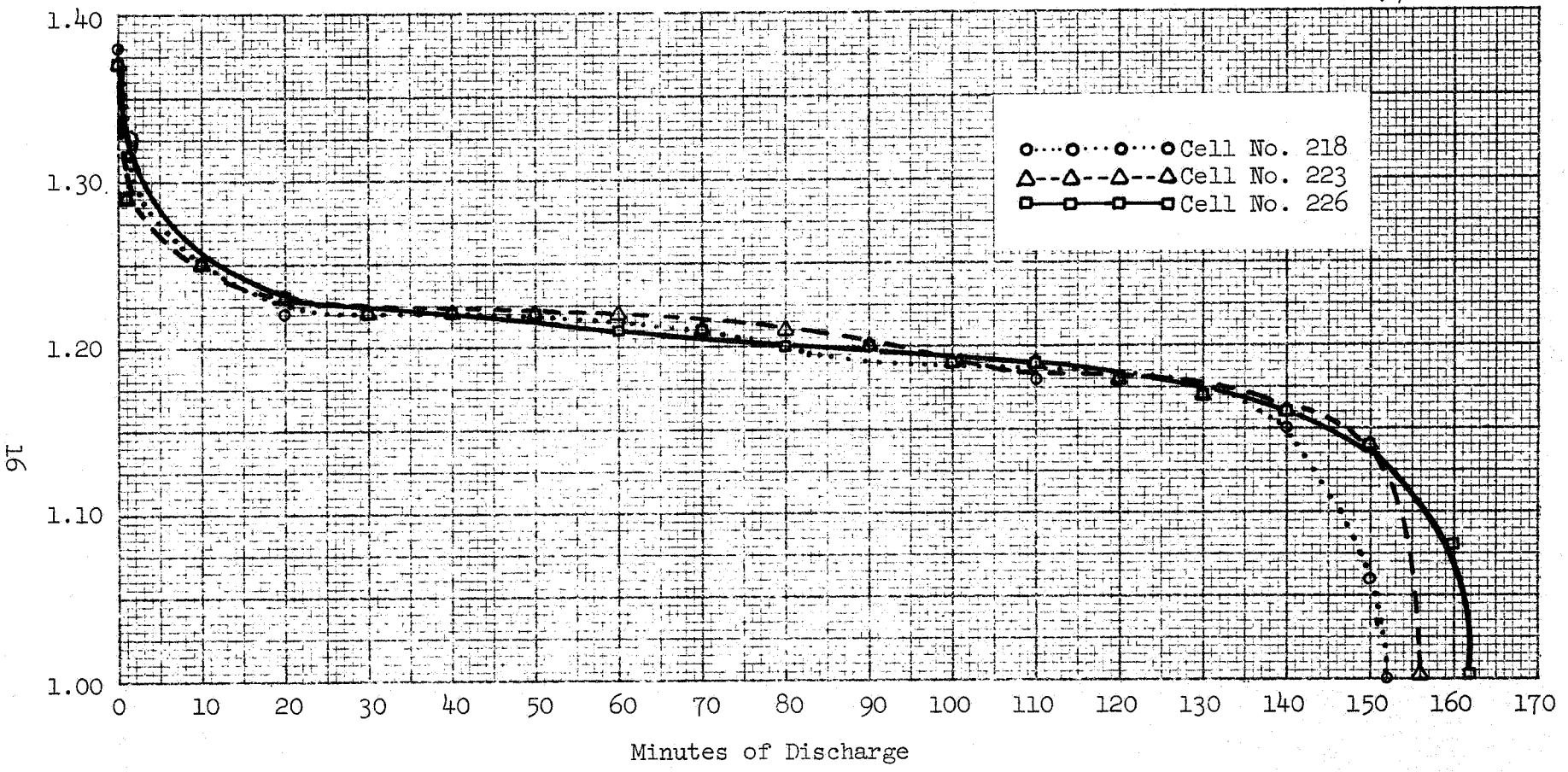
FIGURE 2

QE/C 68-14



CHARACTERISTIC 2-HOUR RATE DISCHARGE CURVES
GULTON 20 AMPERE-HOUR STANDARD CELLS

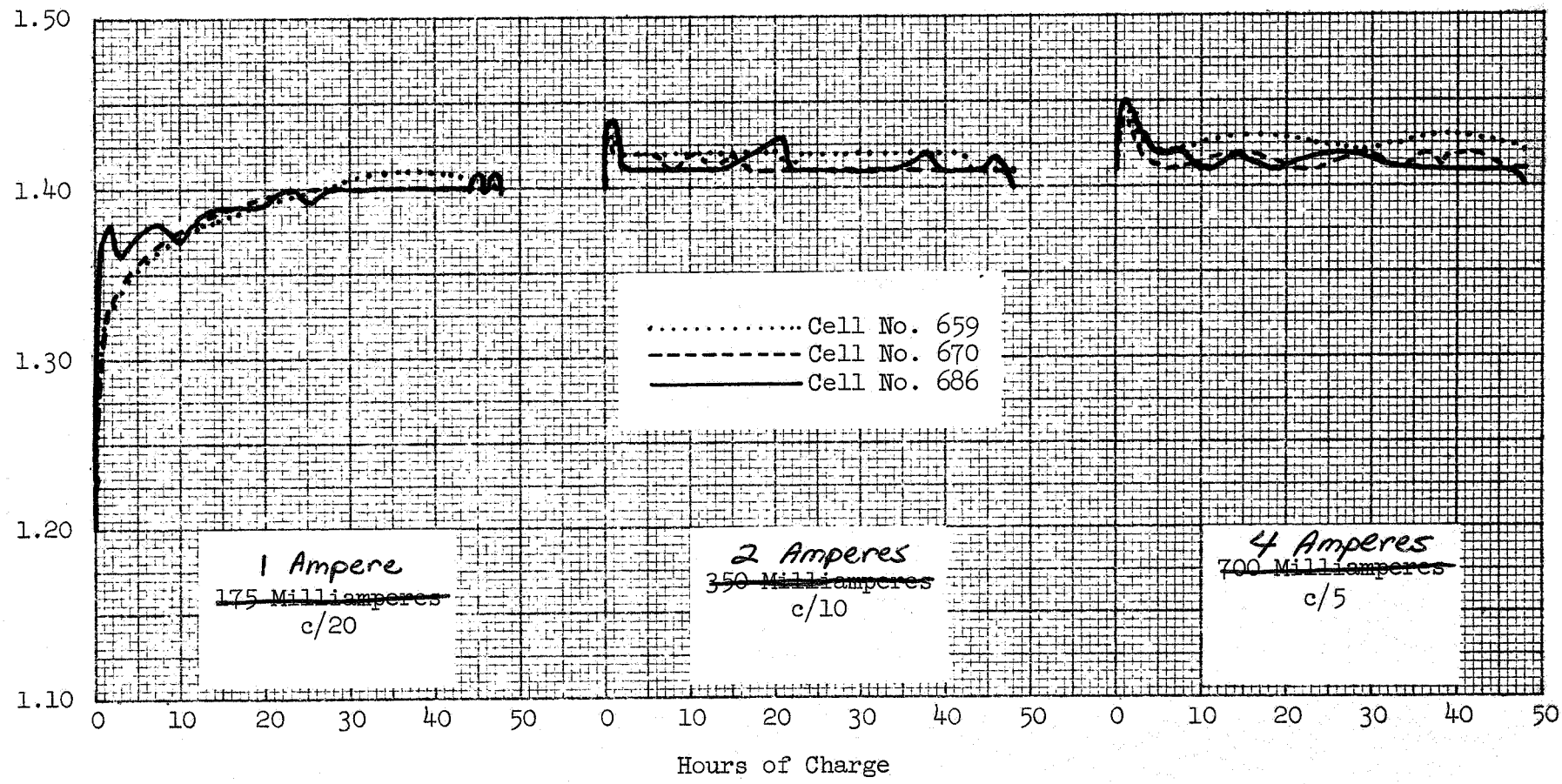
FIGURE 3



CHARACTERISTIC 2-HOUR RATE DISCHARGE CURVES
GULTON 20 AMPERE-HOUR ADHYDRODE CELLS

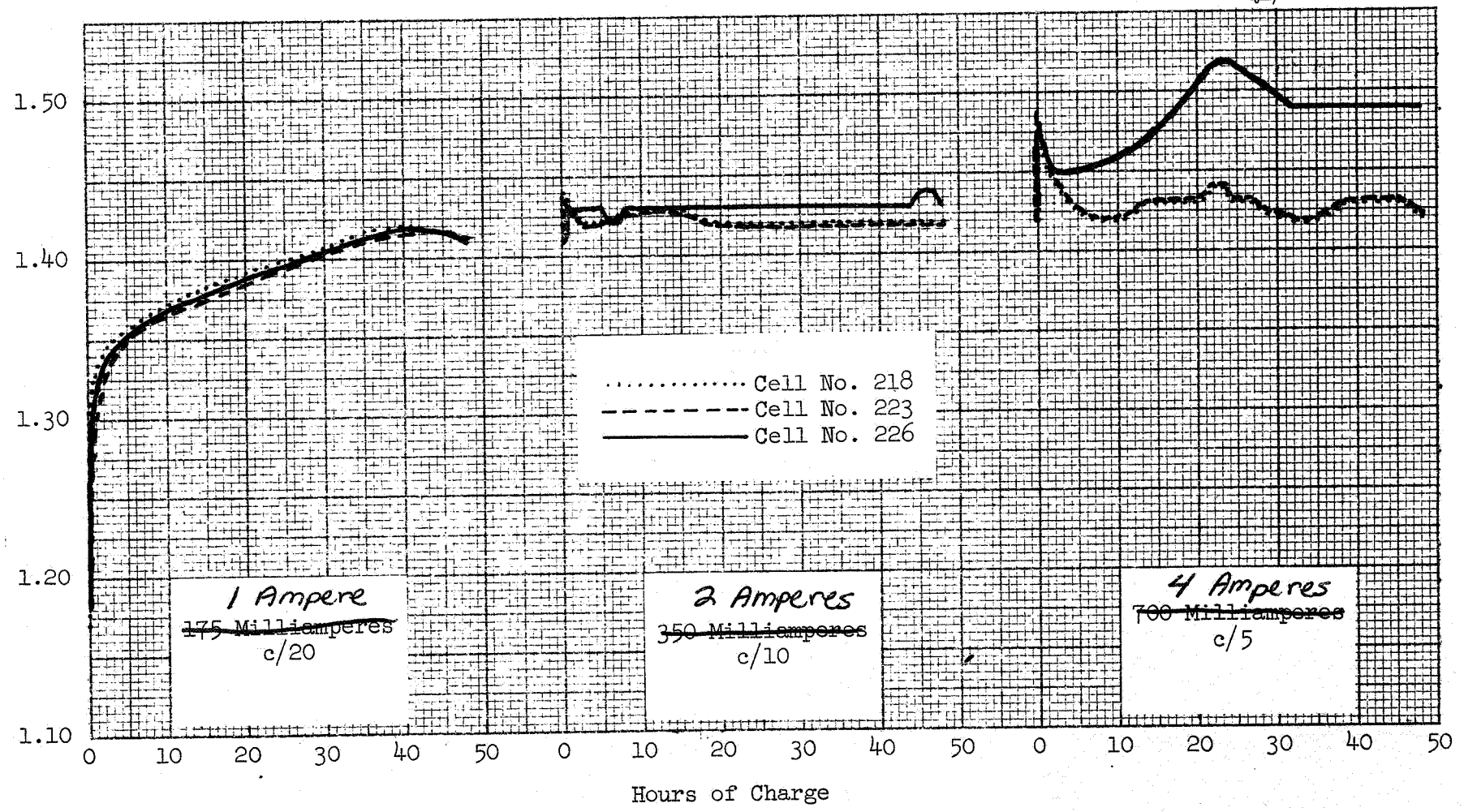
FIGURE 4

QE/C 68-14



CHARACTERISTIC 48-HOUR OVERCHARGE CURVES
GULTON 20 AMPERE-HOUR STANDARD CELLS

FIGURE 5



CHARACTERISTIC 48-HOUR OVERCHARGE CURVES
GULTON 20 AMPERE-HOUR ADHYDRODE CELLS

FIGURE 6

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15 MAY 1968

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To: National Aeronautics and Space Administration, Goddard Space Flight Center (716.2, Mr. T. J. Hennigan), Greenbelt, Maryland 20771

Subj: Correction to Figures 5 and 6 of NAD Crane Report QE/C 68-14

Ref: (a) NAD Crane ltr QEWE-HMS:bc 8900 of 16 April 1968 to NASA

1. Figures 5 and 6 of NAD Crane report QE/C 68-14 of 2 February 1968, which was forwarded by reference (a), are in error. The overcharge currents shown in the three spaces at the bottom of the figures should be corrected to read as follows:

1 Ampere c/20	2 Amperes c/10	4 Amperes c/5

C. G. LYNCH
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